

Synchrotron emission driven by the Cherenkov-drift instability in active galactic nuclei.

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ABSTRACT

In the present paper we study generation of the synchrotron emission by means of the feedback of Cherenkov drift waves on the particle distribution via the diffusion process. It is shown that despite the efficient synchrotron losses the excited Cherenkov drift instability leads to the quasi-linear diffusion (QLD), effect of which is balanced by dissipation factors and as a result the pitch angles are prevented from damping, maintaining the corresponding synchrotron emission. The model is analyzed for a wide range of physical parameters and it is shown that the mechanism of QLD guarantees the generation of electromagnetic radiation from soft X -rays up to soft γ -rays, strongly correlated with Cherenkov drift emission ranging from IR up to UV energy domains.

Subject headings: galaxies: active - plasmas - instabilities - radiation mechanisms: non-thermal

1. Introduction

Recently an interest to X -ray and γ -ray emission from active galactic nuclei (AGNs) has substantially increased due to new observational data from satellite telescopes. Investigations of cosmic objects passed to a new stage when in 2007 the AGILE (Astro-rivelatore Gamma a Immagini Leggero) satellite and in 2008 the Fermi spacecraft were launched. These new observational results are of fundamental importance in studying the emission properties of several X -ray and γ -ray sources, like AGNs, pulsars, gamma ray bursts etc.

Most commonly it is believed that highly relativistic electrons do not participate in the synchrotron emission. Energy losses are so efficient that particles very rapidly lose their energies and transit to the ground Landau states. In spite of this, as it was shown in a series of articles by Osmanov (2011, 2010a,b); Osmanov & Chkheidze (2011); Osmanov & Machabeli (2010), the syn-

chrotron radiation still might account for the radiation processes produced by very energetic particles in AGNs.

According to Kazbegi et al. (1991) in strong magnetic fields the plasma may induce the unstable cyclotron waves. On the other hand, as it was shown by Lominadze et al. (1979), these waves via the QLD affect the particle distribution as along as across the magnetic field lines. Such a feedback of cyclotron waves on particles will inevitably lead to the creation of the pitch angles, restoring the synchrotron emission. Apart from AGNs the process of the QLD was applied to pulsars as well and it was shown that the mentioned mechanism is very efficient for pulsar magnetospheres (Lominadze et al. 1979; Machabeli & Usov 1979; Malov & Machabeli 2001; Machabeli & Osmanov 2009, 2010).

This approach makes possible for the synchrotron radiation to be a working mechanism despite strong energy losses. A very interesting

property of the QLD is that it enables to produce highly correlated radiation in two different energy bands. In this process one has two major forces that influence the particle distribution function. On the one hand, the diffusion attempts to increase the values of the pitch angles of resonant particles and, on the other hand, the emitting particles are affected by dissipative forces intending to decrease their pitch angles. It was shown in the papers listed above that under certain conditions the dissipative and diffusion factors balance each other, the physical system reaches stationary state and the pitch angles saturate. Consequently, the cyclotron emission by means of the diffusion redistributes resonant particles and as a result, the synchrotron emission is produced. This mechanism guarantees strongly correlated radiation in two different energy bands.

In the framework of this emission model, the radiation is generated in two energy bands because of the feedback of the excited cyclotron waves on particles by means of the QLD, which start to radiate in the synchrotron regime. In general similar emission mechanism can be driven not only via the cyclotron waves. Particularly, in the present paper, unlike the aforementioned articles, we consider the feedback of the Cherenkov-drift waves on the resonant particles via the QLD. This process should also switch the synchrotron radiation mechanism and must provide correlated emission in different energy domains.

The paper is arranged in the following way. In section II, we introduce the theory of the quasi-linear diffusion. In section III, we apply the model to AGNs and in section IV, we summarize our results.

2. Model

In this section we develop the model of the QLD of particles driven by means of the feedback of the Cherenkov drift modes in the magnetospheres of AGNs. Normally, in the mentioned region, with the typical lengthscales $l \sim 10^{13-14} \text{ cm}$, values of the Lorentz factors of electrons may vary from ~ 1 to $\sim 10^7$. This range for the Lorentz factors was implied in Osmanov et al. (2007); Rieger & Aharonian (2008), where it was shown that acceleration of particles becomes extremely efficient in the light cylinder zone (a hy-

pothetical area, where the linear velocity of rotation exactly equals the speed of light) due to the relativistic effects of rotation. We apply methods developed in the mentioned papers in the framework of the present article. For simplicity one can assume that the magnetosphere of AGN is composed of a low energy plasma component with the Lorentz factors γ_p , and a highly relativistic part - the beam component with γ_b . As we have already mentioned, the synchrotron radiation is suppressed for strongly relativistic electrons. In particular, one can see that the cooling timescale of beam electrons is given by $t_{syn} \sim \gamma_b mc^2 / P_{syn}$, where m is the electron's mass, c is the speed of light, $P_{syn} \approx 2e^4 \gamma_b^2 B^2 / 3m^2 c^3$ is the single particle synchrotron emission power, B is the magnetic induction and e is the electron's charge. By taking into account typical values of the magnetic field in an ambient close to the supermassive black hole (SMBH), $B \approx 10^{1-4} \text{ G}$, one can see that the cooling timescale varies in the following interval $5 \times (10^{-7} - 1) \text{ s}$. On the other hand, close to the light cylinder zone, due to the efficient curvature drift instability, the magnetic field lines significantly twist (Osmanov 2008), therefore, the lengthscale is still of the order of l and the corresponding plasma escape timescale, l/c , is of the order of $3 \times 10^{2-3} \text{ s}$. As we see, the synchrotron cooling timescale is much less than the kinematic timescale, therefore, in AGN magnetospheres, due to the strong energy losses, particles very rapidly transit to the ground Landau states resulting in the termination of the emission process.

Generally speaking, as was explained by Shapakhidze et al. (2002), the necessary condition for the development of the Cherenkov drift instability (ChDI) is the presence of the beam component in plasmas. Since the magnetic field lines are always curved, it is evident that the electrons will drift along a direction perpendicular to the plane of the curved magnetic field lines with the following velocity

$$u_x = \frac{\gamma_b c^2}{\omega_B \rho}, \quad (1)$$

where $\omega_B = eB/(mc)$ is the cyclotron frequency of the particle and ρ is the curvature radius of the magnetic field line. It is clear that for highly relativistic particles ($\gamma_b \gg 1$) the drift velocity becomes significant and the ChDI with the following resonance condition arises (Shapakhidze et al.

2002)

$$\omega - k_{\parallel} v_{\parallel} - k_x u_x = 0, \quad (2)$$

where k_{\parallel} and v_{\parallel} are the longitudinal components (along the magnetic field line) respectively of the wave vector and the particle velocity, and k_x is the wave vector's component along the drift direction.

During the process of ChDI the transverse (t) waves might be excited, having the growth rate (Shapakhidze et al. 2002)

$$\Gamma_k = \frac{\pi}{2} \frac{\omega_b^2}{\omega} \frac{\gamma_b}{\gamma_p^2} A_k, \quad (3)$$

where

$$\omega = \frac{\omega_b \gamma_b c}{\gamma_p^{3/2} u_x} \quad (4)$$

is the frequency of Cherenkov emission, $\omega_b = \sqrt{4\pi n_b e^2/m}$ is the Langmuir frequency, n_b is the beam number density, $A_k = (k_r/k_x)^2$ and k_r is the component of the wave vector along the curvature radius of magnetic field lines. Throughout the paper we assume $A_k = 1$ (Kazbegi et al. 1991).

During their motion in a nonuniform magnetic field the charged relativistic particles undergo two major dissipative forces: \mathbf{H} - responsible for conservation of the adiabatic invariant (Landau & Lifshitz 1971)

$$H_{\perp} = -\frac{c}{\rho} p_{\perp}, \quad H_{\parallel} = \frac{c}{\rho p_{\parallel}} p_{\perp}^2, \quad (5)$$

and the synchrotron radiation reaction force (Landau & Lifshitz 1971)

$$F_{\perp} = -\alpha \frac{p_{\perp}}{p_{\parallel}} \left(1 + \frac{p_{\perp}^2}{m^2 c^2} \right), \quad F_{\parallel} = -\frac{\alpha}{m^2 c^2} p_{\perp}^2, \quad (6)$$

where $\alpha = 2e^2 \omega_B^2 / 3c^2$, p_{\perp} and p_{\parallel} are transversal and longitudinal components of the momentum, respectively.

The effect of the aforementioned dissipative forces decreases the pitch angles, which inevitably causes attenuation of the corresponding synchrotron emission process. The situation drastically changes due to diffusion as along as across the magnetic field lines, since this process tries to increase the pitch angles. Under certain conditions diffusion and dissipation forces might balance each other and as a result the synchrotron radiation process will be maintained. The QLD influences the particle distribution function and

the corresponding kinetic equation can be written as (Chkheidze et al. 2011; Machabeli & Usov 1979; Malov & Machabeli 2001)

$$\begin{aligned} \frac{\partial f^0(\mathbf{p})}{\partial t} + \frac{\partial}{\partial p_{\parallel}} \{ [F_{\parallel} + H_{\parallel}] f^0(\mathbf{p}) \} + \\ + \frac{1}{p_{\perp}} \frac{\partial}{\partial p_{\perp}} \{ p_{\perp} [F_{\perp} + H_{\perp}] f^0(\mathbf{p}) \} = \\ = \frac{1}{p_{\perp}} \frac{\partial}{\partial p_{\perp}} \left\{ p_{\perp} D_{\perp, \perp} \frac{\partial f^0(\mathbf{p})}{\partial p_{\perp}} \right\} + \\ + \frac{\partial}{\partial p_{\parallel}} \left\{ D_{\parallel, \parallel} \frac{\partial f^0(\mathbf{p})}{\partial p_{\parallel}} \right\}, \end{aligned} \quad (7)$$

where $f^0(\mathbf{p})$ is the distribution function,

$$\begin{aligned} D_{\perp, \perp} &= 8\pi \left(\frac{u_x}{c} \right)^8 \left(\frac{e}{mc} \right)^2 \frac{W}{\Gamma_k}, \\ D_{\parallel, \parallel} &= 8\pi \left(\frac{u_x}{c} \right)^2 \left(\frac{e}{mc} \right)^2 \frac{W}{\Gamma_k}, \end{aligned} \quad (8)$$

are the diffusion coefficients. Here W is the energy density of the excited waves and we have taken into account that $D_{\perp, \parallel} = D_{\parallel, \perp} = 0$ (Shapakhidze et al. 2003).

It should be noted that pitch angles ψ acquired by particles during the QLD are small enough to apply the condition, $\partial/\partial p_{\perp} \gg \partial/\partial p_{\parallel}$, which reduces the kinetic equation (7) to the following form

$$\begin{aligned} \frac{\partial f^0}{\partial t} + \frac{1}{p_{\perp}} \frac{\partial}{\partial p_{\perp}} (p_{\perp} [F_{\perp} + H_{\perp}] f^0) = \\ = \frac{1}{p_{\perp}} \frac{\partial}{\partial p_{\perp}} \left(p_{\perp} D_{\perp, \perp} \frac{\partial f^0}{\partial p_{\perp}} \right). \end{aligned} \quad (9)$$

On the light cylinder lengthscale one can simplify Eq. (9) by estimating the ratio F_{\perp}/H_{\perp} . Taking into account parameters typical for the light cylinder area, one obtains

$$\frac{H_{\perp}}{F_{\perp}} \approx 350 \times \frac{M_8}{A_{0.1} L_{40}} \times \left(\frac{10^{-3} \text{rad}}{\psi} \right)^2 \times \frac{10^7}{\gamma_b} \times \frac{R_{lc}}{\rho}, \quad (10)$$

where $A_{0.1} = \Omega/(0.1\Omega_{max})$, Ω and $\Omega_{max} \approx c^3/(GM_{BH})$ are the dimensionless angular velocity, the actual angular velocity and the maximum angular velocity of the supermassive black hole, M_{BH} is its mass, $G \approx 6.67 \times 10^{-8} \text{dyne cm}^2/\text{g}^2$ is the gravitational constant, $L_{40} = L/10^{40} \text{erg/s}$ and L are the dimensionless and actual values of

luminosity of AGN, $M_8 = M_{BH}/(10^8 M_\odot)$ is its dimensionless mass, M_\odot is the solar mass and $R_{lc} = c/\Omega$ is the light cylinder radius.

In general, it is evident from Eq. (10) that depending on physical parameters one has two major regimes: (I) $F_\perp \ll H_\perp$ (II) $H_\perp \ll F_\perp$.

In the framework of the first approximation one can neglect its contribution of F_\perp in Eq. (9), which for the stationary case ($\partial/\partial t = 0$) has the following solution

$$f_I(p_\perp) = C \exp\left(\int \frac{H_\perp}{D_{\perp,\perp}} dp_\perp\right) = C e^{-\left(\frac{p_\perp}{p_{\perp 0}^I}\right)^2}, \quad (11)$$

where

$$p_{\perp 0}^I = \left(\frac{2\rho D_{\perp,\perp}}{c}\right)^{1/2}. \quad (12)$$

As we see from Eq. (11), particles are distributed differently for different values of transverse momentum, therefore, it is natural to examine the average value of p_\perp which in turn defines the mean value of the pitch angles. A straightforward calculation leads to the following expression

$$\langle p_\perp \rangle_I = \frac{\int_0^\infty p_\perp f_I(p_\perp) dp_\perp}{\int_0^\infty f_I(p_\perp) dp_\perp} = \frac{p_{\perp 0}^I}{\sqrt{\pi}}, \quad (13)$$

and the corresponding average value of the pitch angle

$$\langle \psi \rangle_I = \frac{\langle p_\perp \rangle_I}{p_\parallel} = \frac{1}{\sqrt{\pi}} \frac{p_{\perp 0}^I}{p_\parallel}. \quad (14)$$

For the second case ($H_\perp \ll F_\perp$), the distribution function reduces to

$$f_{II}(p_\perp) = C \exp\left(\int \frac{F_\perp}{D_{\perp,\perp}} dp_\perp\right) = C e^{-\left(\frac{p_\perp}{p_{\perp 0}^{II}}\right)^4}, \quad (15)$$

where

$$p_{\perp 0}^{II} = \left(\frac{4\gamma_b m^3 c^3 D_{\perp,\perp}}{\alpha}\right)^{1/4}, \quad (16)$$

and the corresponding mean values of the transverse momentum and the pitch angle respectively are given by

$$\langle p_\perp \rangle_{II} = \frac{\int_0^\infty p_\perp f_{II}(p_\perp) dp_\perp}{\int_0^\infty f_{II}(p_\perp) dp_\perp} = \frac{\sqrt{\pi}}{4\Gamma(\frac{5}{4})} p_{\perp 0}^{II}, \quad (17)$$

$$\langle \psi \rangle_{II} = \frac{\langle p_\perp \rangle_{II}}{p_\parallel} = \frac{\sqrt{\pi}}{4\Gamma(\frac{5}{4})} \frac{p_{\perp 0}^{II}}{p_\parallel}, \quad (18)$$

where $\Gamma(x)$ is the gamma function.

3. Discussion

As we see from the results of the previous section, the Cherenkov-drift instability strongly influences the particle distribution by means of the QLD and prevents the synchrotron emission. In this section we apply the developed model to AGNs and study the production of the nonthermal emission.

For this purpose we consider the light cylinder zone of the magnetosphere. In this area the value of the magnetic induction might be estimated in the framework of the equipartition approximation. Thus, we assume that the magnetic field energy density is of the order of plasma energy density, which defines the magnetic induction

$$B_{lc} \approx 5.5 \times A_{0.1} \times L_{40}^{1/2} G. \quad (19)$$

As we see the magnetic field is quite strong and since in this area particles normally achieve very high Lorentz factors, $\sim 10^{6-7}$, the resulting synchrotron emission should be quite efficient. In particular, relativistic electrons moving in a strong magnetic field and having the pitch angles expressed by Eqs. (14,18), will emit the photons with energies (Rybicki & Lightman 1979)

$$\epsilon_{keV}^I \approx 1.2 \times 10^{-11} \gamma_b^2 B_{lc} \frac{1}{\sqrt{\pi}} \frac{p_{\perp 0}}{p_\parallel}. \quad (20)$$

$$\epsilon_{keV}^{II} \approx 3 \times 10^{-12} \gamma_b^2 B_{lc} \frac{\sqrt{\pi}}{\Gamma(\frac{5}{4})} \frac{p_{\perp 0}^{II}}{p_\parallel}. \quad (21)$$

In the framework of the quasi-linear diffusion, the problem is usually treated by means of the method of iteration. It is evident that the instability has to be saturated by means of nonlinear effects (the corresponding study is not in the scope of the paper) and since there is some energy budget, it is clear that after the process is relaxed, the energy of waves must be of the same order of that of plasmas associated with the energy budget (Malov & Machabeli 2001). Therefore, in the framework of the paper we assume $W \sim \gamma_b m c^2 n_b$.

As a first example we consider the case when H_\perp exceeds the corresponding component of the radiation reaction force. By combining Eqs.(3,8,12,20) one can study the emission characteristics. In Fig. 1 we show the dependence of energy of radiated synchrotron photons on the beam

electron Lorentz factors for different values of γ_p . The set of parameters is $A_k = 1$, $M_8 = 1$, $A_{0.1} = 1$, $L = 10^{40} \text{erg/s}$, $\gamma_p \in [1; 3; 10]$, $n_b = n_{GJ}$, where $n_{GJ} \equiv \Omega B_{lc}/(2\pi ec)$ is the Goldreich-Julian number density of electrons (Ruderman & Sutherland 1975). From Eqs. (12) one obtains that the pitch angles vary in the range $\sim 3 \times 10^{-3} - 2 \times 10^{-2} \text{rad}$, that is in a good agreement with the assumption $H_\perp \gg F_\perp$ (see Eq. 10).

As it is evident from the plots the photon energy is a continuously increasing function of γ_b , which is a natural consequence of the fact that more energetic electrons emit more energetic photons. ϵ_{keV} has the similar behaviour with respect to the plasma component Lorentz factor. By increasing γ_p the corresponding photon energy increases as well. In particular, by combining Eqs. (3,4,8,12) one can see that $\epsilon_{keV} \propto D_{\perp,\perp}^{1/2} \propto \gamma_p^{1/4}$. As it is clear from the figure, the QLD guarantees the emission in the keV energy domain (X-rays), which in turn must be strongly correlated with the lower energy emission provided by Cherenkov-drift instability. From Eqs. (1,4) one can obtain energy of photons corresponding to the Cherenkov drift waves

$$\epsilon_{eV}^{Ch} \approx 0.06 A_{0.1} \gamma_p^{-3/2} \times \left(\frac{n_b}{n_{GJ}} \right)^{1/2} \times \left(\frac{L}{10^{40} \text{erg/s}} \right)^{1/2}. \quad (22)$$

We see that for the mentioned physical parameters the Cherenkov instability produces the IR photons with energies $\sim (2 \times 10^{-3} - 6 \times 10^{-2}) \text{eV}$, and since the QLD is achieved by means of the feedback of these waves on particles, it is evident that the IR emission must be strongly connected to the soft X-ray radiation (1–12)keV.

Generally speaking, the instability is supposed to be efficient if the corresponding growth rate is high enough. From Eq. (3) we obtain

$$\Gamma_k \approx 6.5 \times 10^{-3} \times \gamma_p^{-1/2} \times \frac{\gamma_b}{10^7} \times \left(\frac{n_b}{n_{GJ}} \right)^{1/2} \times \left(\frac{L}{10^{40} \text{erg/s}} \right)^{1/2} s^{-1}. \quad (23)$$

It is clear that the instability timescale, $t_{inst} \sim 1/\Gamma_k$ is of the order of 500s. On the other hand, particles are moving inside the magnetosphere and the kinematic timescale (escape timescale) $t_{kin} \sim R_{lc}/c \approx 5 \times 10^3 \text{s}$ exceeds the instability timescale,

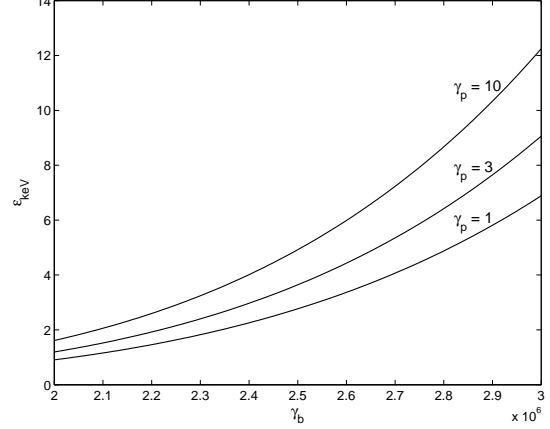


Fig. 1.— Behaviour of energy of radiated synchrotron photons with the beam electron Lorentz factors for different values of plasma component Lorentz factors in case of $H_\perp \gg F_\perp$. The set of parameters is $A_k = 1$, $M_8 = 1$, $A_{0.1} = 1$, $L = 10^{40} \text{erg/s}$, $\gamma_p \in [1; 3; 10]$, $n_b = n_{GJ}$.

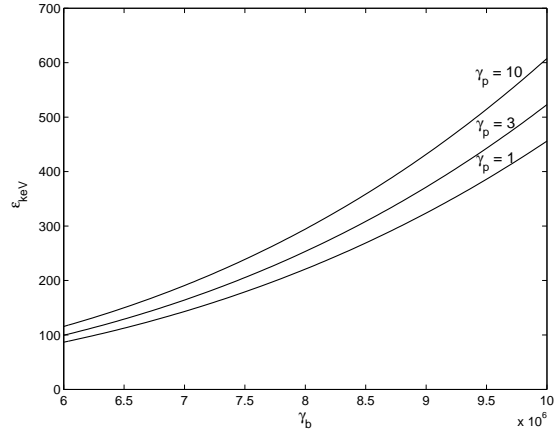


Fig. 2.— Dependence of energy of synchrotron photons on γ_b for different values of plasma component Lorentz factors in case of $H_\perp \ll F_\perp$. The set of parameters is $A_k = 1$, $M_8 = 1$, $A_{0.1} = 1$, $L = 10^{40} \text{erg/s}$, $\gamma_p \in [1; 3; 10]$, $n_b = n_{GJ}$.

which indicates high efficiency of the Cherenkov-drift mechanism.

From Eq. (10) it is clear that H_{\perp}/F_{\perp} is sensitive with the Lorentz factor of beam components and the pitch angles (note that ψ itself nontrivially depends on γ_b see Eqs. (14,18)) and hence, for other parameters the relation between forces may be different. Therefore, it is reasonable to consider another limit, ($H_{\perp} \ll F_{\perp}$) and see what happens in this particular situation.

In Fig. 2 we show the dependence of energy of synchrotron emission on beam Lorentz factors for different values of γ_p . The set of parameters is $A_k = 1$, $M_8 = 1$, $A_{0.1} = 1$, $L = 10^{40}$ erg/s, $\gamma_p \in [1; 3; 10]$, $n_b = n_{GJ}$. The difference from the previous case is γ_b , which varies from 6×10^6 to 10^7 . From Eq. (10) it is clear that for the mentioned parameters the following approximation, $H_{\perp} \ll F_{\perp}$ is satisfied. From the plots we see that ϵ_{keV} lies in the interval $\sim (100 - 600)$ keV, which is much higher than the photon energies shown in Fig. 1 being a result of a more steep dependance $\epsilon_{keV} \propto \gamma_b^{13/4}$ (see Eqs.(3,8,16,21)). Since the expression of ϵ_{eV}^{Ch} does not depend on the beam Lorentz factors, the hard X-ray radiation is strongly connected with the corresponding Cherenkov-drift emission generated in the same energy domain as in the previous case: IR band.

The emission pattern strongly depends on the values of the AGN luminosity. In particular, in the framework of the model, we use the equipartition magnetic field and the induction becomes dependent on L . Such a dependance is motivated by the fact that the diffusion coefficient behaves as, $1/B^8$ (see Eq. (8)) which leads to $\epsilon_{keV} \propto L^{-9/8}$ (see Eqs. (14,18,20,21)). On the other hand, unlike the results shown on the previous two graphs, in this case ϵ_{eV}^{Ch} also depend on the AGN luminosity, and since synchrotron and Cherenkov-drift emission are generated simultaneously, it is interesting to investigate them both.

In Fig. 3 we present the behaviour of the synchrotron photon energy on the Cherenkov-drift emission for different values of angular momentum. Unlike the previous cases it is worthwhile to consider higher luminosity values: $[0.5 - 1] \times 10^{42}$ erg/s. We do not examine extreme luminous sources, because in this case the Lorentz factors of relativistic electrons might be less than consid-

ered in the present paper. The set of parameters is $A_k = 1$, $M_8 = 1$, $A_{0.1} \in [1; 5; 10]$, $\gamma_b = 10^7$, $\gamma_p = 1$, $n_b = n_{GJ}$. It is straightforward to show that the synchrotron radiation reaction force is less than the force responsible for conservation of the adiabatic invariant. It is clear from the plots that ϵ_{keV} (ϵ_{eV}^{Ch}) is a continuously decreasing function, which is a direct result of the fact that with bolometric luminosity ϵ_{keV} decreases ($\propto L^{-9/8}$), whereas the energies of Cherenkov-drift photons behave as $L^{1/2}$ (see Eq. (22)). We also show the plots for different values of angular momentum of the supermassive black hole. As it is clear, bigger the angular momentum, the bigger the resulting emission energy for both mechanisms. In particular, from Eqs. (22,8,16,21)) one can see that ϵ_{keV} and ϵ_{eV}^{Ch} both are increasing functions of A . According to the present results, we see that for the mentioned parameters, the quasi-linear diffusion provides the generation of synchrotron emission from the soft up to hard X-rays: $\sim (10 - 250)$ keV. These energies are strongly connected with the Cherenkov-drift emission in the energy interval $\sim (1 - 14)$ eV, corresponding to emission from IR up to extreme UV.

4. Summary

The main aspects of the present work can be summarized as follows:

1. In the present paper we studied the role of Cherenkov drift emission in maintaining the synchrotron regime despite the efficient energy losses.
2. It is shown that in the magnetospheres of supermassive black holes the excited Cherenkov drift instability is efficient enough to influence the particle distribution by means of the quasi-linear diffusion.
3. In the framework of the model, we examine equation governing the process of the QLD. It is shown that for physically reasonable parameters the synchrotron radiation reaction force prevails over other dissipative factors. By taking into account this fact the corresponding kinetic equation is analytically solved and the emission characteristics are estimated

4. The emission pattern is investigated for a variety of physical parameters. We found that for typical AGNs the QLD might guarantee the excitation of strongly coupled Cherenkov drift emission in the eV domain and the synchrotron radiation in the keV energy band.

As we have already seen, the Cherenkov-drift instability might guarantee the maintenance of the synchrotron emission process for a variety of AGN. Another important issue we would like to address is the problem of radiation spectral index, which, in some sense, will complete the problem. It is necessary to investigate this task as well, therefore, sooner or later we are going to examine it.

Acknowledgments

We are very grateful to Prof. George Machabeli and Dr. David Shapakidze for valuable discussions and helpful suggestions on the manuscript.

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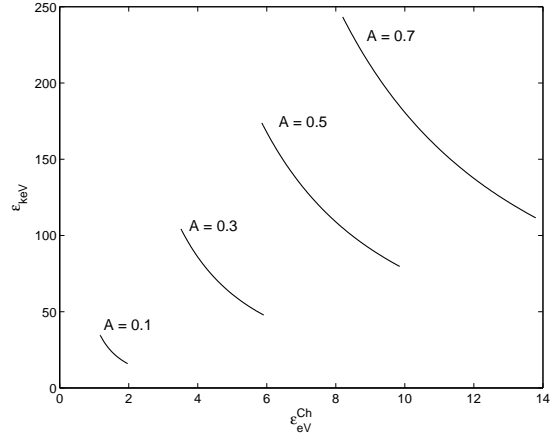


Fig. 3.— Behaviour of ϵ_{keV} with ϵ_{eV}^{Ch} for different values of A in case of $H_{\perp} \gg F_{\perp}$. The bolometric luminosity varies in the interval $[0.5 - 1] \times 10^{42} \text{erg/s}$. The set of parameters is $A_k = 1$, $M_8 = 1$, $A_{0.1} \in [1; 5; 10]$, $\gamma_b = 10^7$, $\gamma_p = 1$, $n_b = n_{GJ}$.